Homeostasis in Reptiles and Amphibians

Homeostasis

- Water balance
- Heat balance
- Water and heat in the environment

Homeostasis

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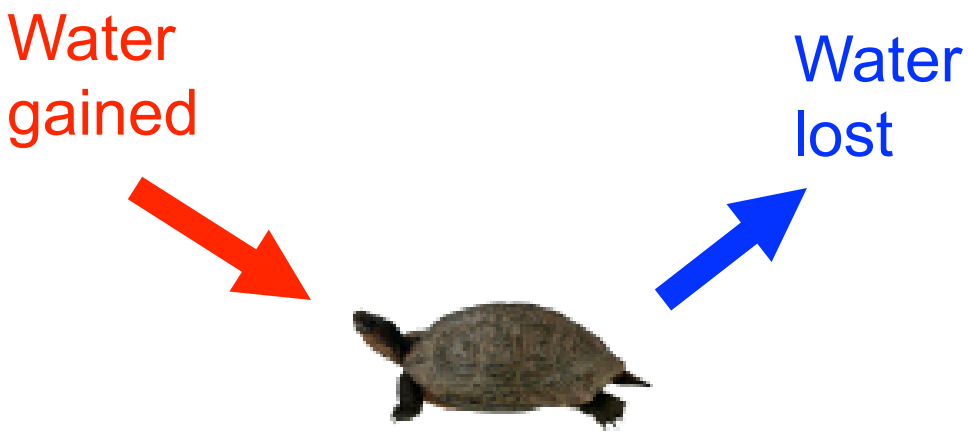
Water balance



At water balance:

Water gained = Water lost

Why does this matter?

- Organisms are mostly water (70-80%)
- Chemical reactions take place in water
- Circulation through blood
- Salt balance equally important
- Water interacts with temperature

Taking in water

liquid water

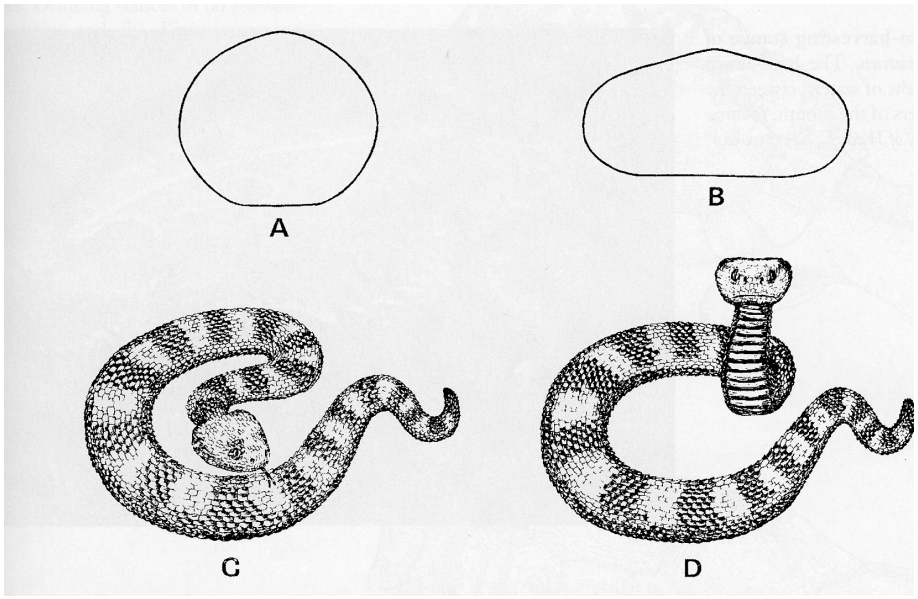
preformed water

metabolic water

Taking in water

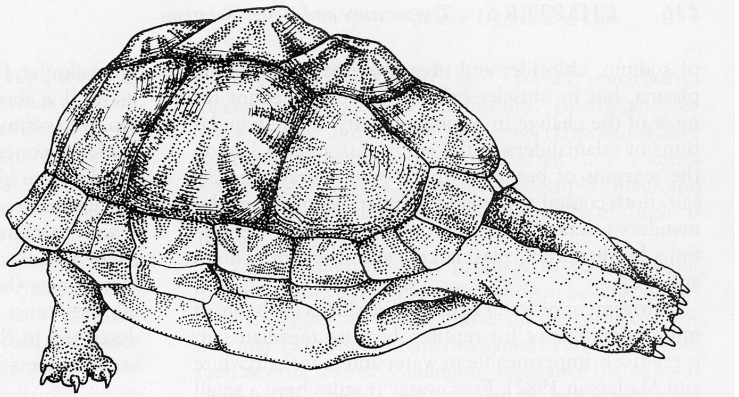
Liquid Water

- Reptiles drink from pools, puddles, etc.
- Can also collect liquid water in clever ways

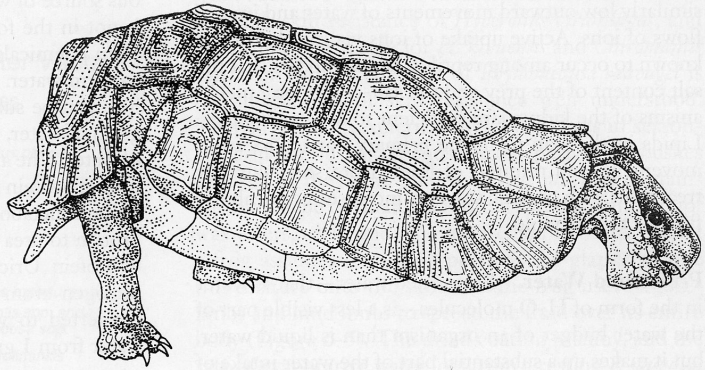


Namib Desert viper *Bitis peringueyi*

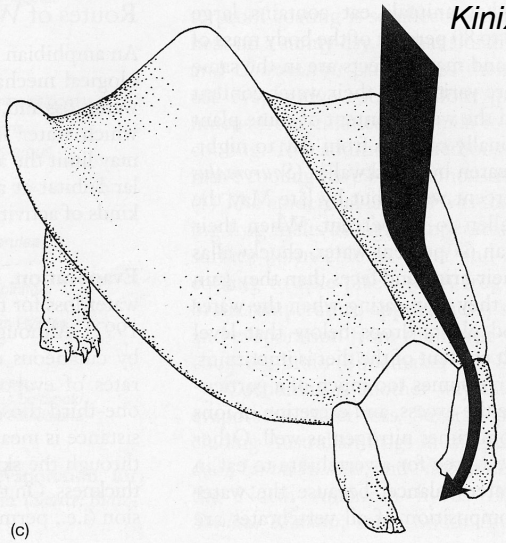
Louw 1972



(a) *Psammobates tentorius*



(b) *Kinixys homeana*



(c)

Pough 2004

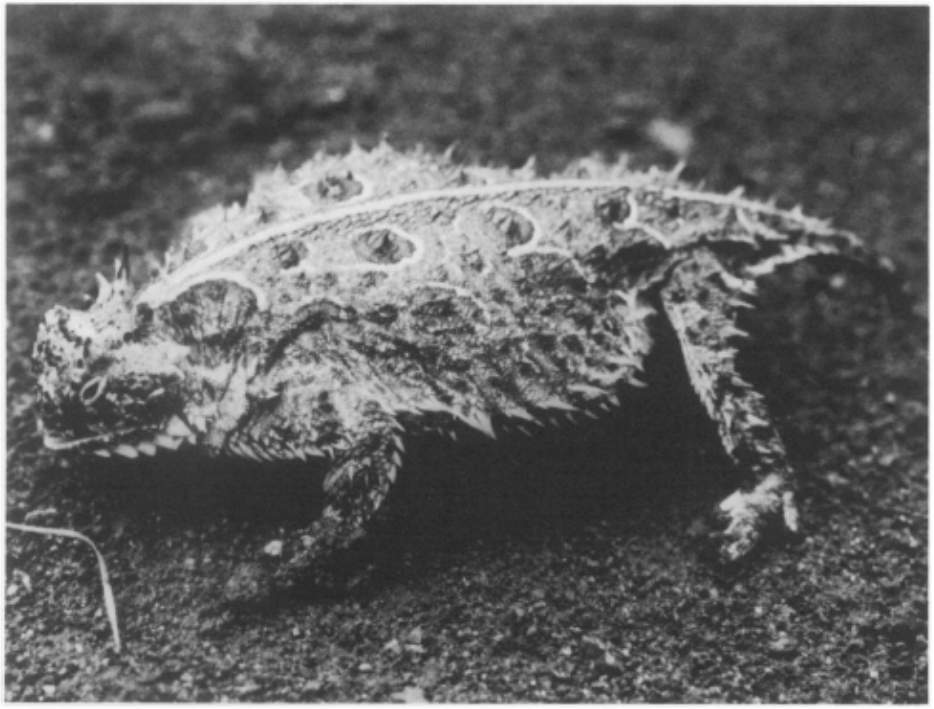


FIG. 1. Adult female *Phrynosoma cornutum* in stereotyped "rain-harvesting" stance, with jaws slightly opened for drinking.

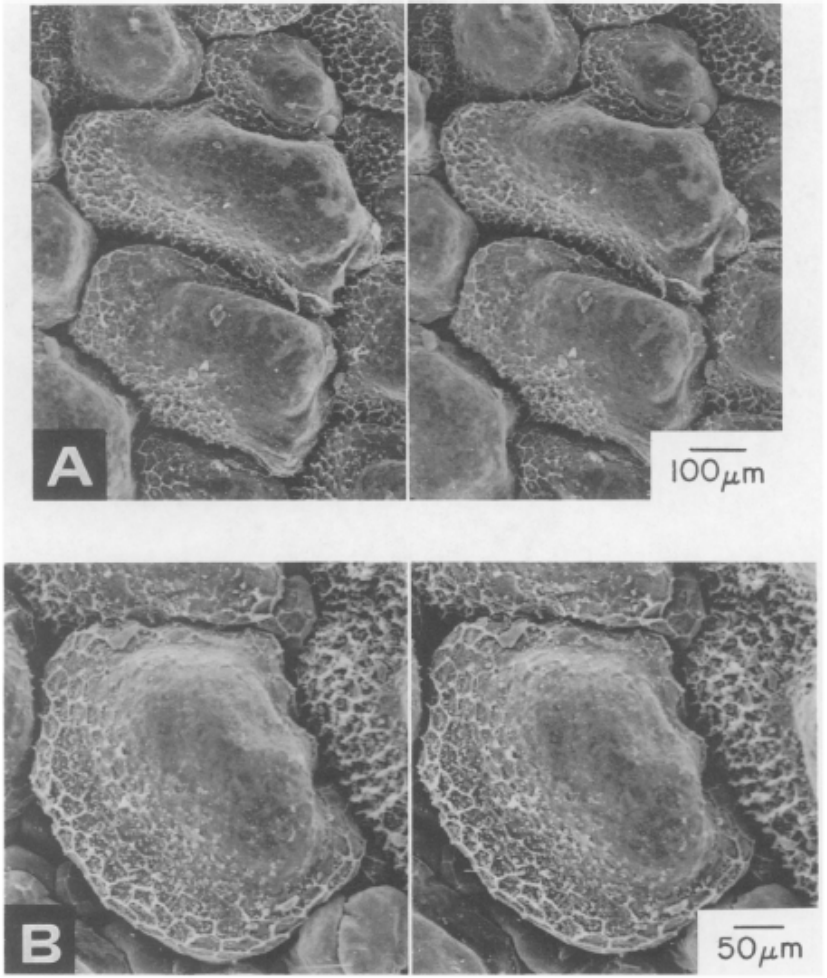


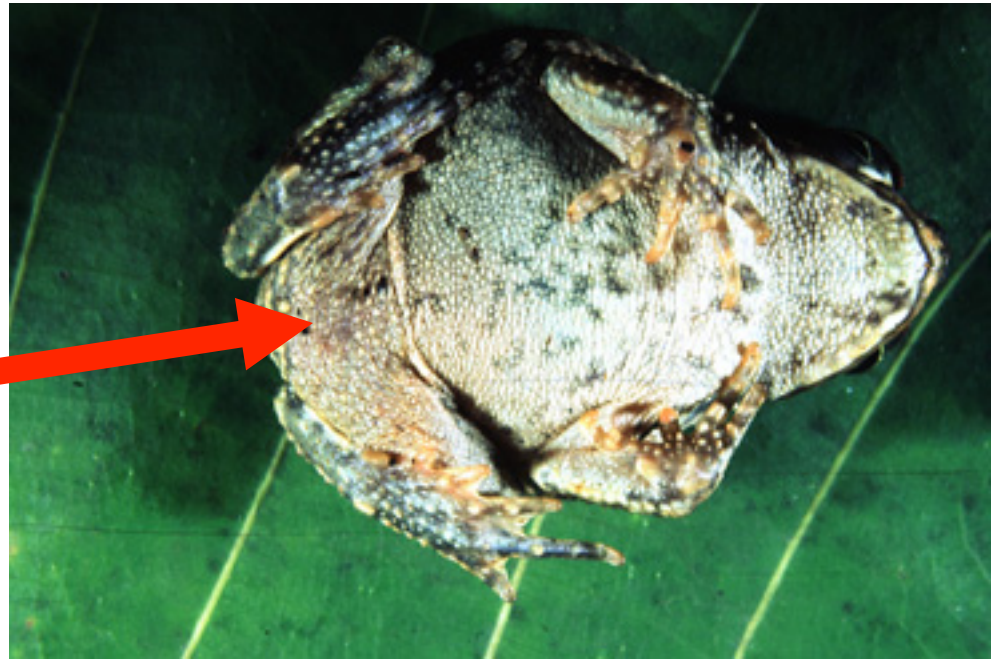
FIG. 2. Stereopaired SEM photographs of dorsal skin of an adult female *Phrynosoma cornutum*: (A) granular scales (between dorsal spines), showing interscalar channels and honeycombed micro-ornamentation around edges of scales; (B) detail of honeycombed micro-ornamentation extending down the walls of the interscalar channels, and small scales within the channels.

Sherbrooke 1990

Liquid Water

- Amphibians do not drink
- They absorb water through their skin

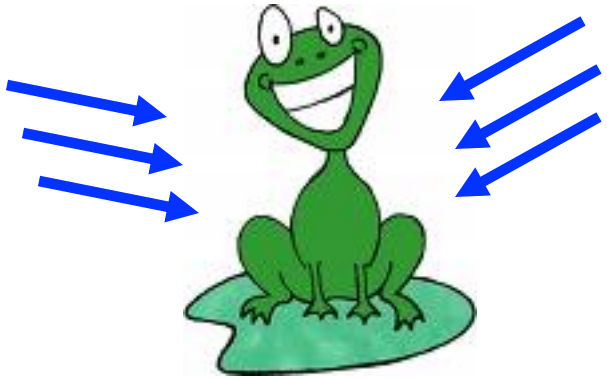
Pelvic patch



Osmosis

- Water moves from low to high salt concentration by osmosis

Spotted frog
Rana luteiventris



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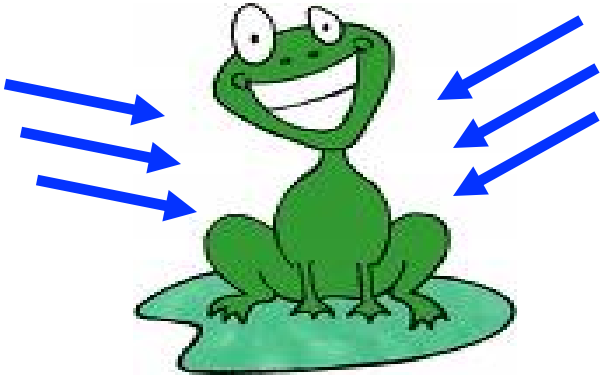

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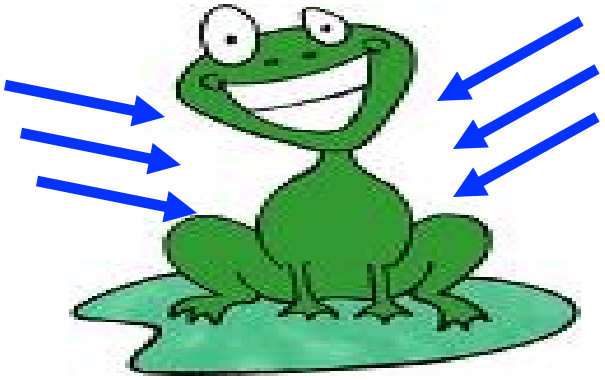

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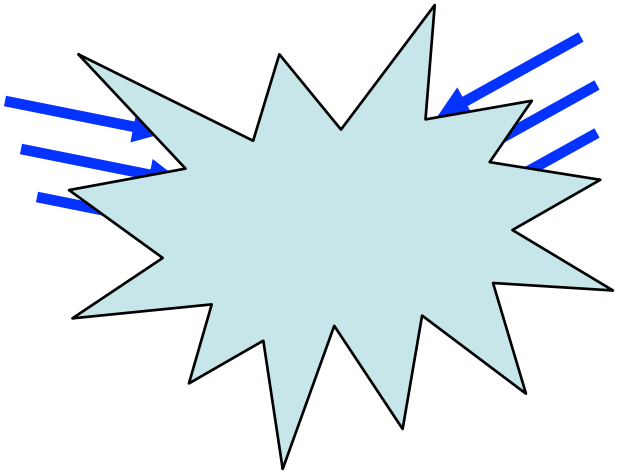

Osmosis

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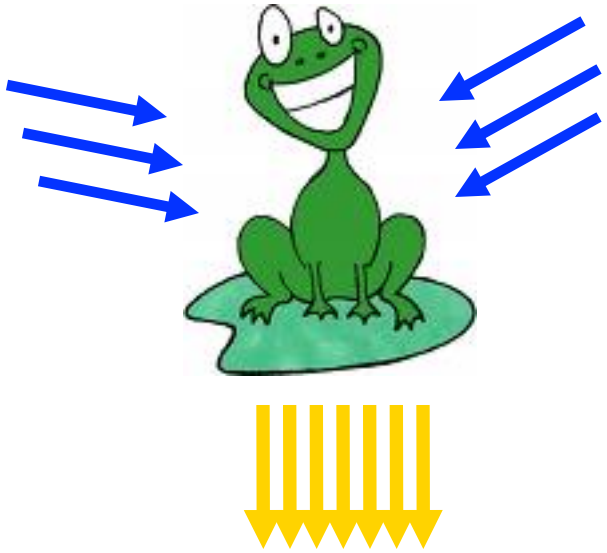
Spotted frog
Rana luteiventris



Osmosis

- Aquatic amphibians in freshwater produce large amounts of dilute urine
- Actively take up ions through skin to make up for losses in urine

Osmosis

- Water moves from low to high salt concentration by osmosis

Crab-eating frog
Rana crancrivora

Osmosis

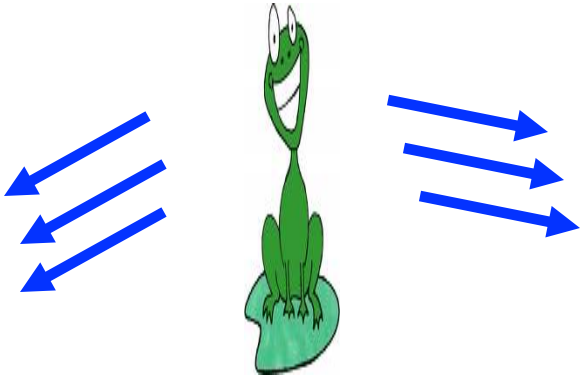
- Water moves from high to low salt concentration by osmosis

Crab-eating frog
Rana crancrivora

Osmosis

- Water moves from high to low salt concentration by osmosis

Crab-eating frog
Rana crancrivora



Saltwater frogs

- A few species of frogs can tolerate brackish water
- Example - crab-eating frog
- Salty body tissues
- Accumulates urea in blood at high concentrations

Taking in water

Preformed water

- Water obtained from food
- Animals are usually 70-80% water
- Plants are more variable - can have positive or negative impact on water balance

Taking in water

Metabolic Water

- Water produced as a byproduct of chemical reactions
- Example: Aerobic respiration

  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
- Can be substantial
  - 1g starch $\rightarrow$ 0.556 g water
  - 1g fat $\rightarrow$ 1.071 g water

Losing water

evaporation

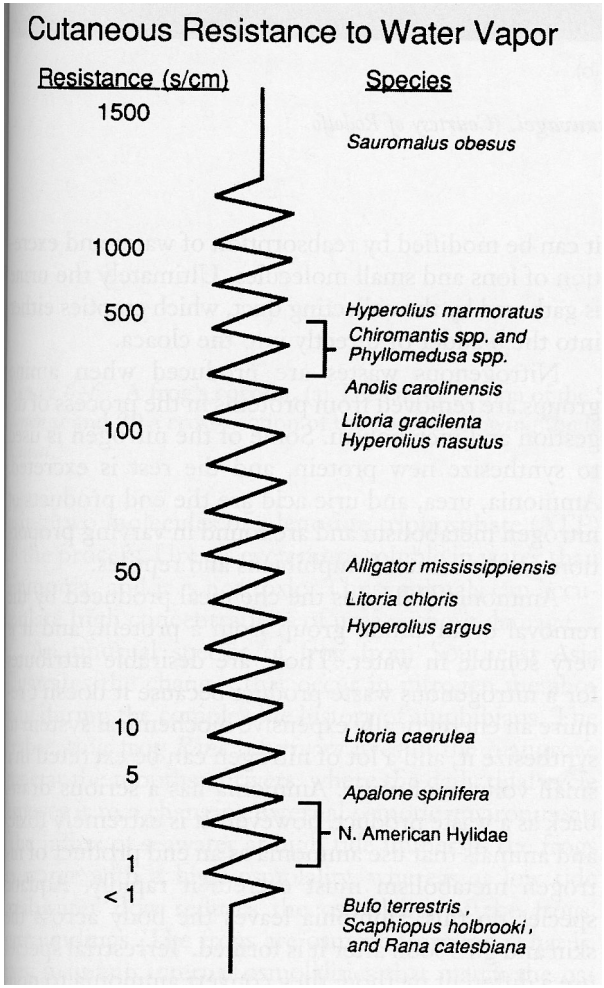
urine and feces

salt glands

Losing water

Evaporation

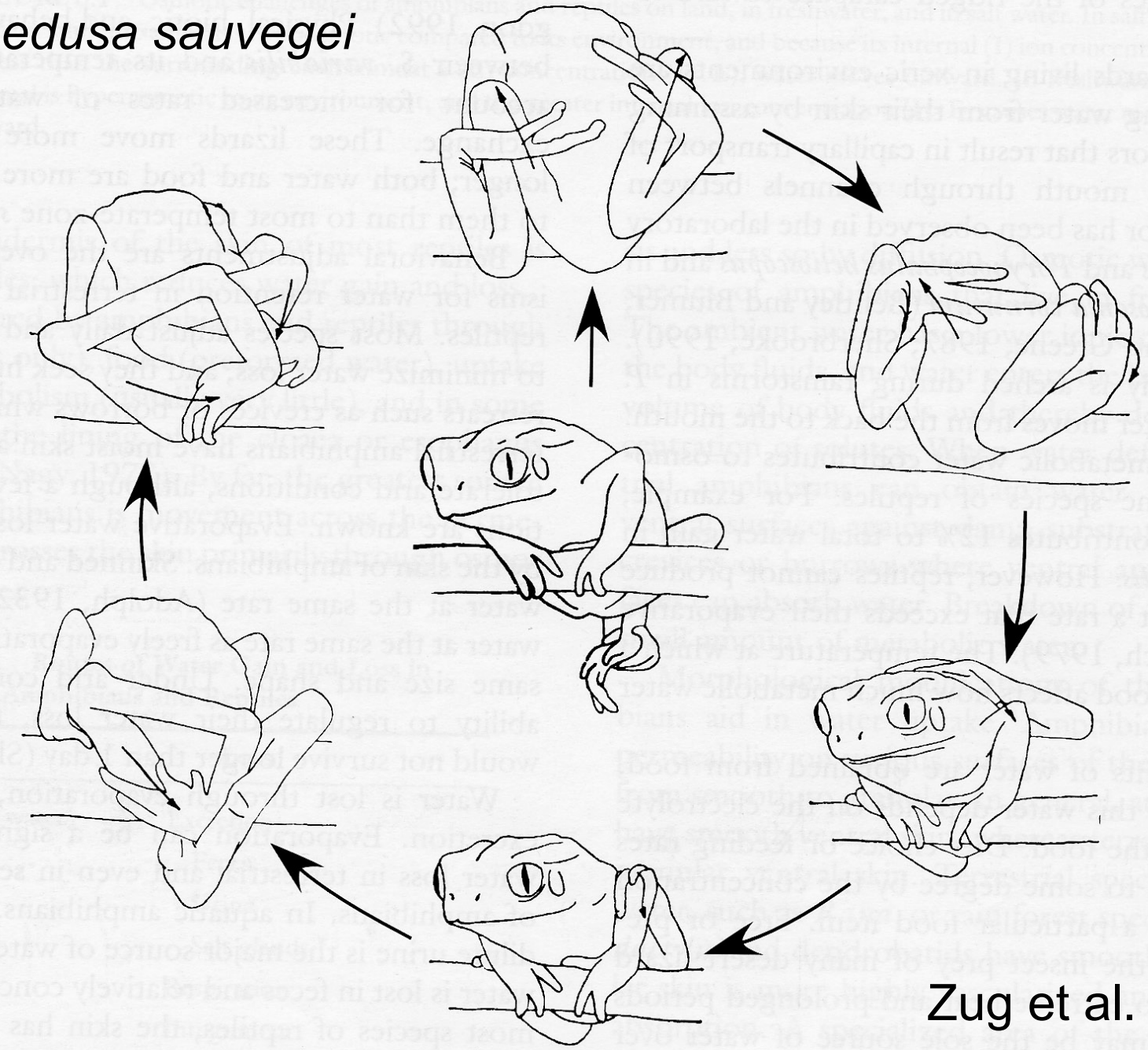
- Major route of water loss for terrestrial amphibians
- Not a major factor for reptiles



Evaporation

- Some amphibians can control water loss
- Example: dried mucus on skin, cocooning

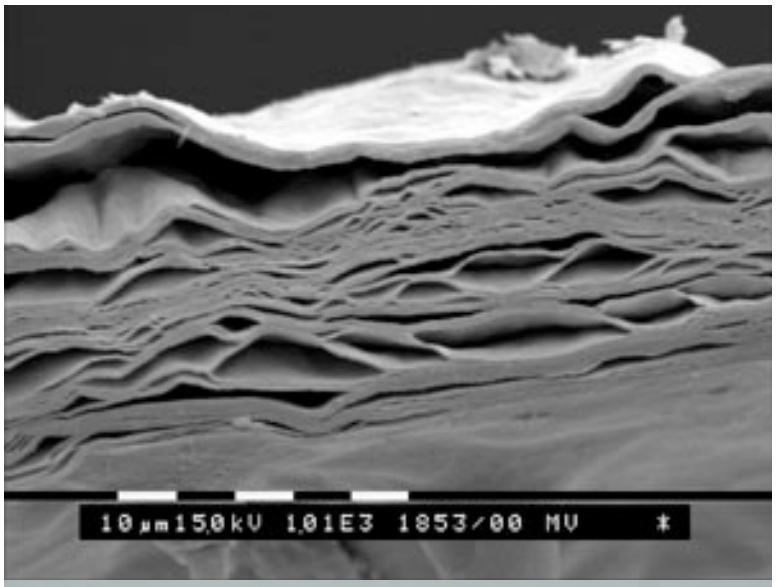
Phyllomedusa sauvegei



Zug et al. 2001

Northern burrowing frog *Neobatrachus aquilonius*

Northern burrowing frog *Neobatrachus aquilonius*



Northern burrowing frog *Neobatrachus aquilonius*

Losing water

evaporation

urine and feces

salt glands

Urine and Feces

- Water is lost in urine and feces
- Key problem: getting rid of nitrogenous wastes

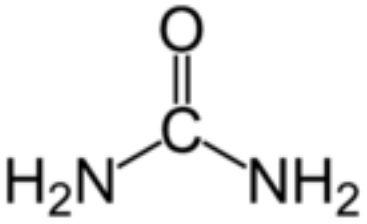
"*Ammonia! Ammonia!*"

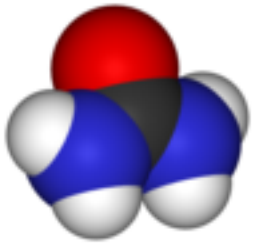
Drawing by R. Grossman; © 1962.
The New Yorker Magazine, Inc.

Urine and Feces

- Three main options
  - Ammonia
    - Soluble in water, but highly toxic
    - Used by aquatic species
  - Urea
    - Soluble in water, nontoxic
    - Used by terrestrial frogs

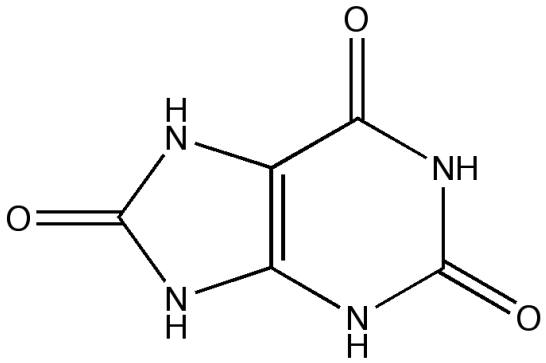
NH_4^+





Urine and Feces

- Three main options
  - Uric acid
    - Insoluble in water
    - White paste
    - Conserves water, still gets rid of nitrogen
    - Bird poop



Losing water

Salt Glands

- Many reptiles have a specialized salt gland that can excrete salt (K^+ and Na^+ ions) in high concentrations
- Saves water

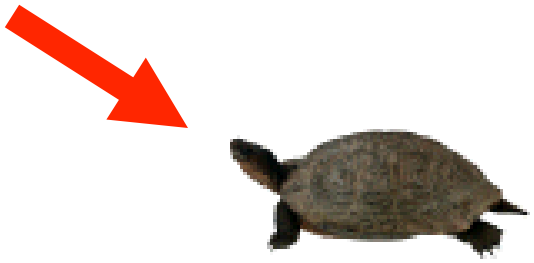

© John White

Homeostasis

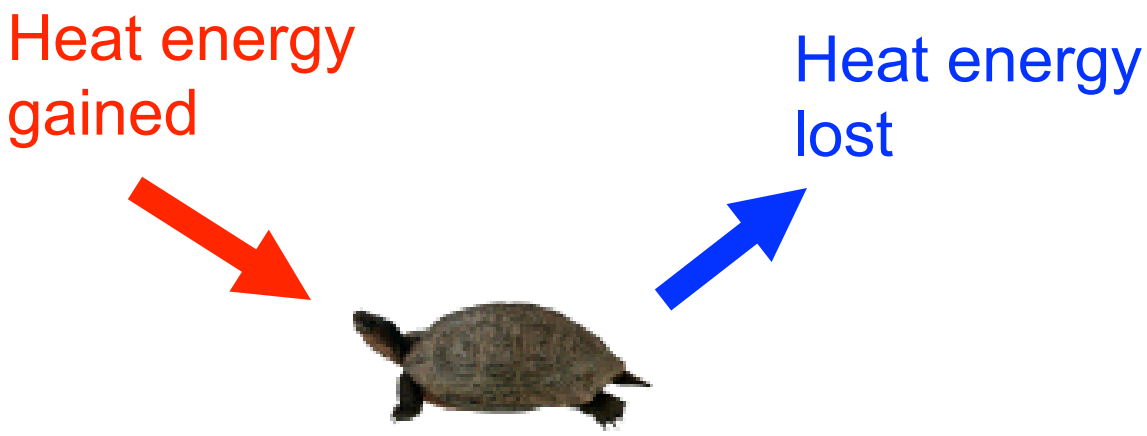
- Water balance
- Heat balance
- Water and heat in the environment

Heat Transfer in Animals

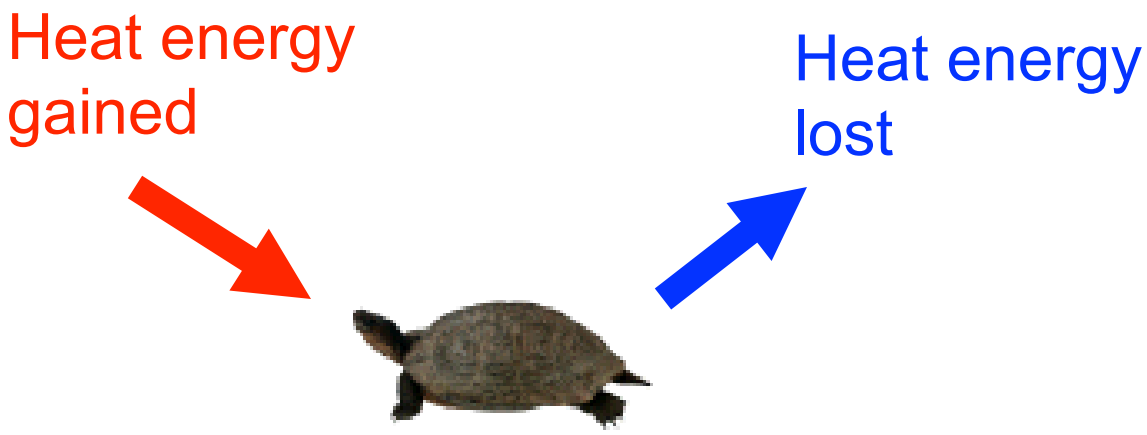
Heat energy gained



Heat Transfer in Animals



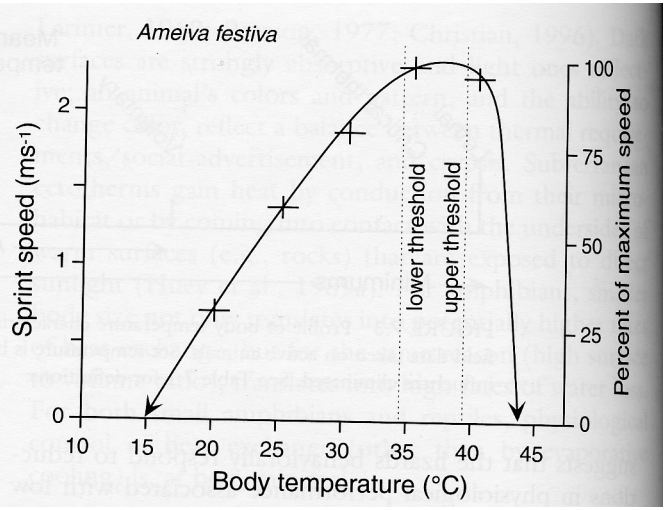
Heat Transfer in Animals

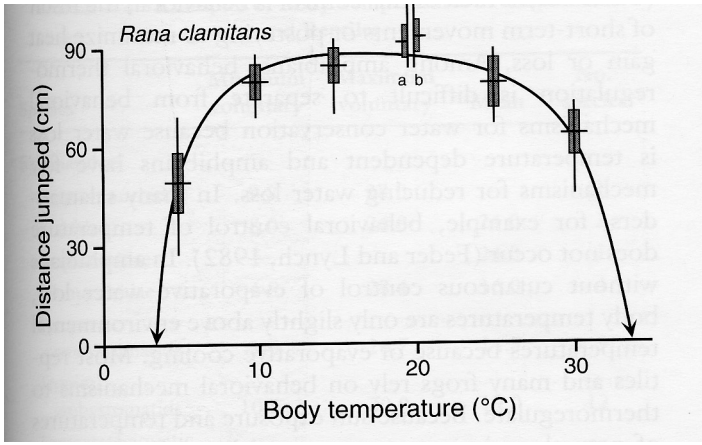


At thermal equilibrium:

Heat energy gained = Heat energy lost

Why does this matter?





Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Heat transfer in animals

solar radiation

metabolic heat

infrared

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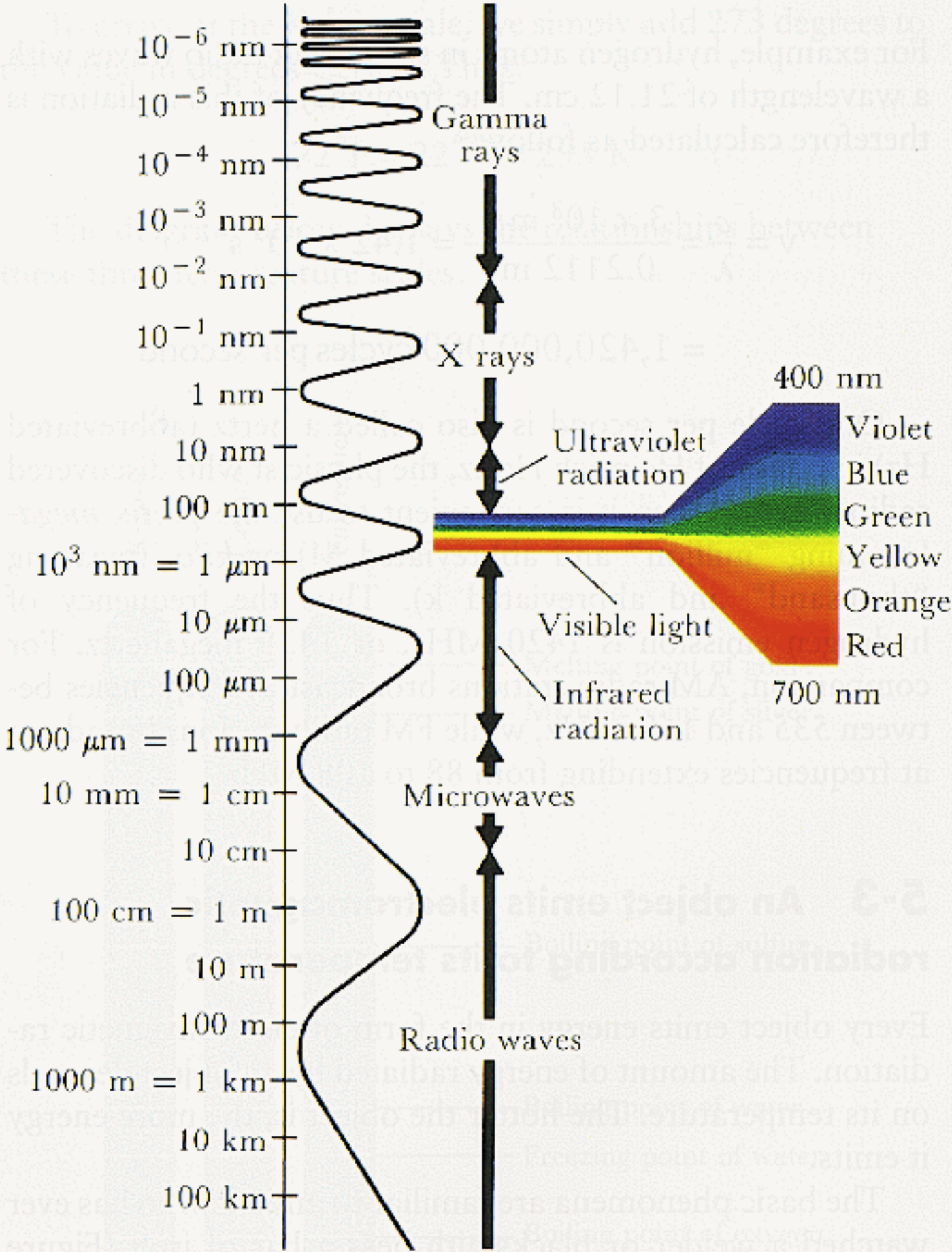
condensation/ evaporation

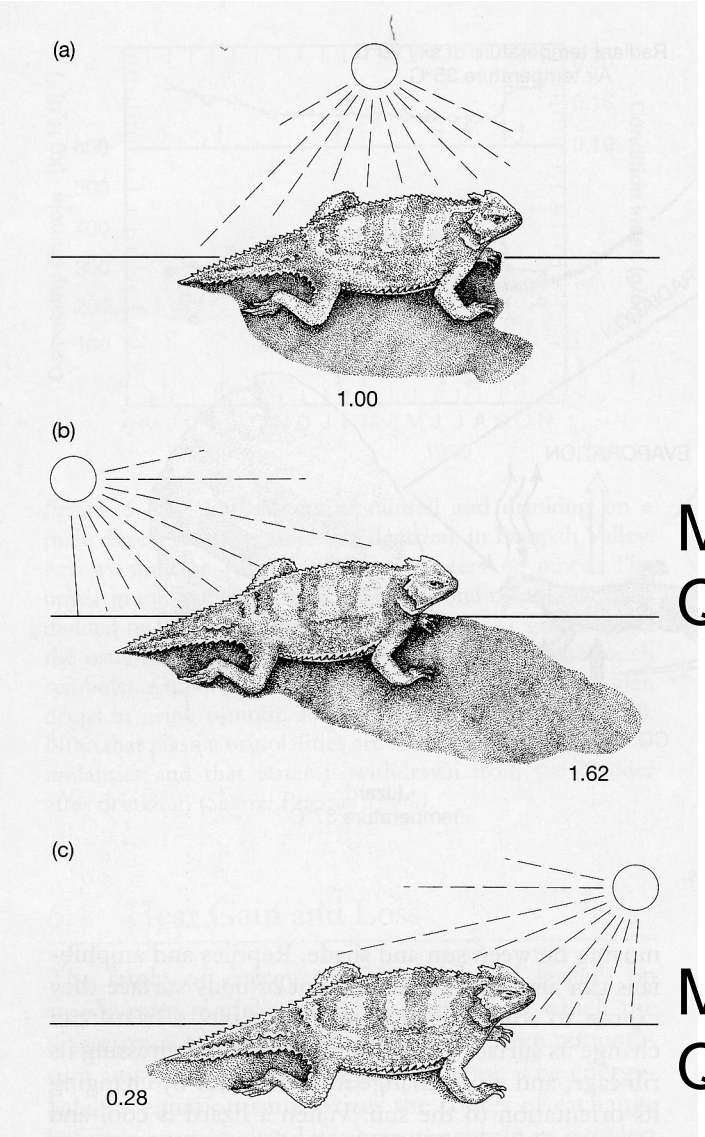
conduction

Heat Transfer in Animals

- 1. Solar radiation - absorbed by the surface of the animal
- 400 - 1500 nanometer wavelengths


10^{-6} nm
10^{-5} nm
10^{-4} nm
10^{-3} nm
10^{-2} nm
10^{-1} nm
1 nm
10 nm
100 nm
10^3 nm = 1 μm
10 μm
100 μm
1000 μm = 1 mm
10 mm = 1 cm
10 cm
100 cm = 1 m
10 m
100 m
1000 m = 1 km
10 km
100 km
Gamma rays
X rays
Ultraviolet radiation
Visible light
Infrared radiation
Microwaves
Radio waves
400 nm
Violet
Blue
Green
Yellow
Orange
Red
700 nm

Horned lizard (*Phrynosoma cornutum*) controlling the absorption of solar radiation by adjusting body posture



Maximize Q_{abs}

Minimize Q_{abs}

Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Metabolic heat production

- Metabolic processes are chemical reactions
- In living things, these reactions tend to produce heat
- Endotherms rely on this heat to maintain constant body temperature
- Most herps do not - although they do still generate some metabolic heat

Metabolic heat production

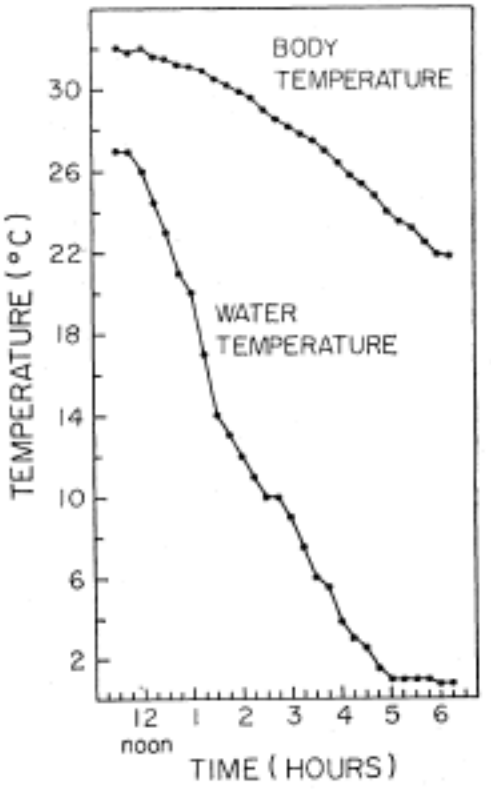


Fig. 1. Body and ambient temperatures for a leatherback turtle during cooling in water.

Frair et al. 1972

Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Infrared radiation

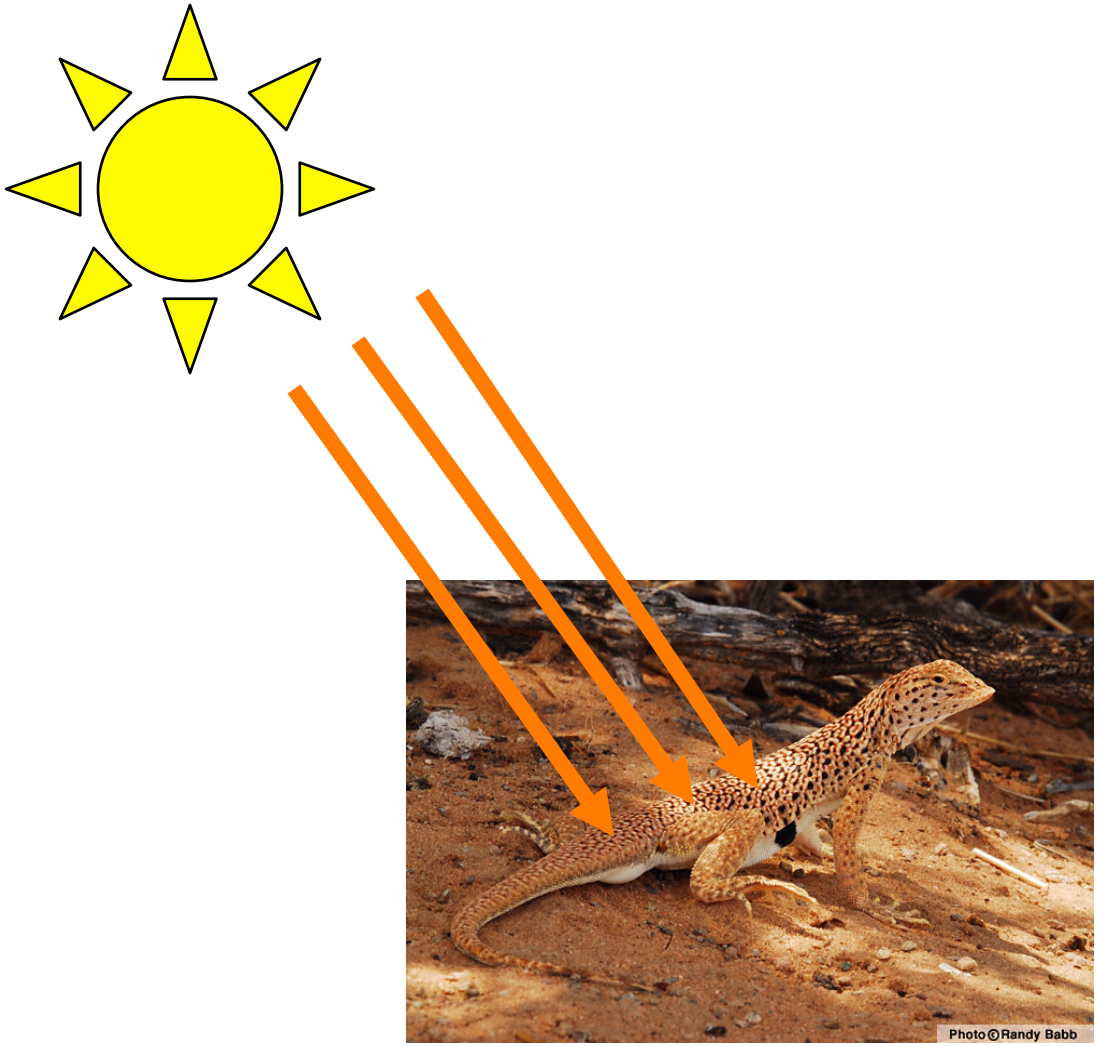
- All objects emit infrared (black body) radiation
- Depends on temperature difference, surface area, and emissivity of skin

Infrared radiation

Mojave fringe-toed lizard *Uma scoparia*

Dorsal - high emissivity
(matte surface)

Ventral - low emissivity
(shiny surface)


Photo©Randy Babb


Photo©Randy Babb

Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Convection

- Heat exchange between the animal and the fluid medium surrounding it
- Flowing air or water
- Depends on temperature difference, surface area, and convective coefficient

Convection

- Convective coefficient dominated by body size

Side-blotched lizard
Uta stansburiana

Chuckwalla
Sauromalus obesus

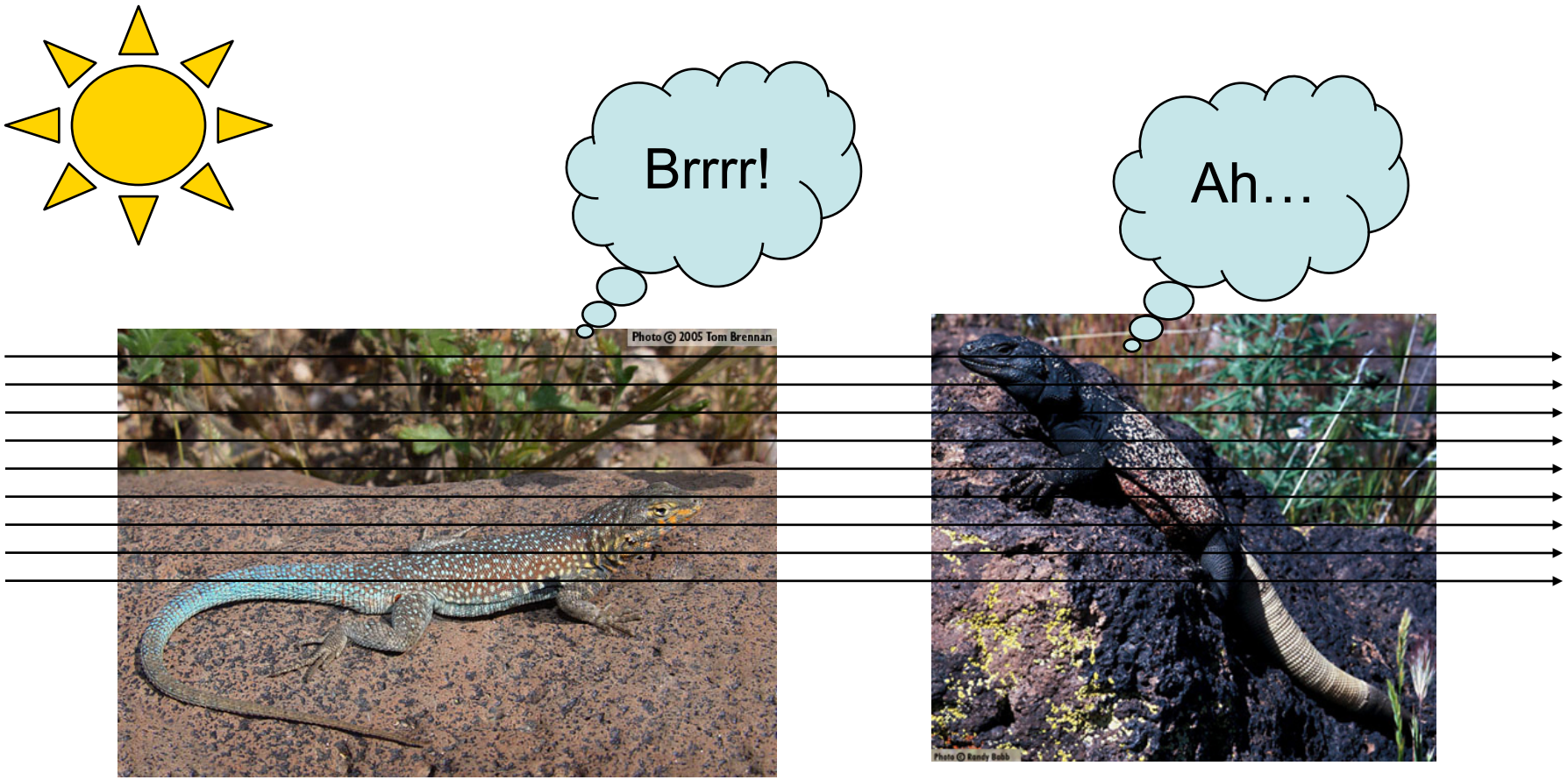
Convection

- Convective coefficient dominated by body size

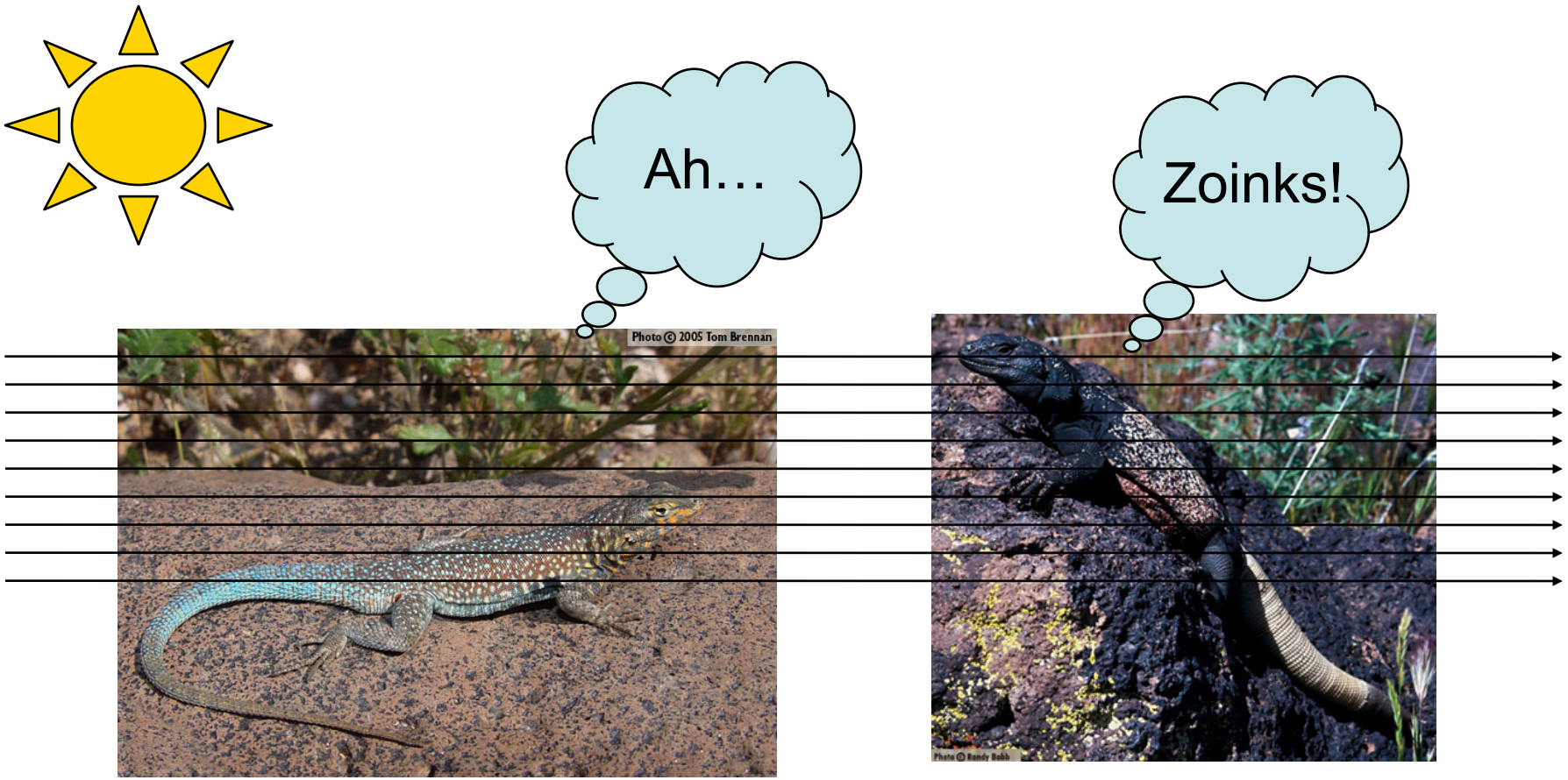
Side-blotched lizard
Uta stansburiana

Chuckwalla
Sauromalus obesus

Morning - cold air temperature



Afternoon - hot air temperature



Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Evaporation

- When water evaporates, it takes in heat
- Cools the surface
- Reptile skin basically impermiable to water - little evaporative cooling
- Some have adaptations - panting, gular fluttering
- Amphibian skin highly permiable
- Bullfrogs can spend an entire day in the hot sun cooling by evaporation

Heat transfer in animals

solar radiation

metabolic heat

infrared

convection

condensation/ evaporation

conduction

Conduction

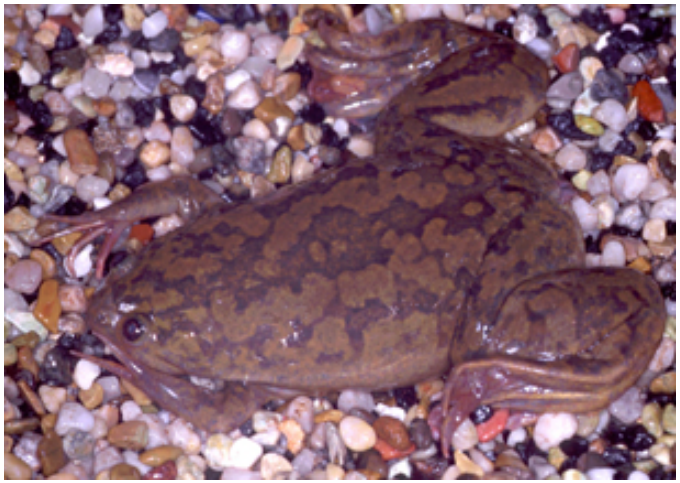
- Transfer of heat to or from surfaces
- Primary source of heat for nocturnal species
- Can adjust posture to affect conduction

Shovel-snouted lizard (*Meroles anchietae*)

Side-Blotched Lizard (*Uta stansburiana*)

Conduction

- Major form of heat exchange in water
- Difficult for aquatic species to have temperatures that differ from surrounding water



Xenopus laevis - African Clawed Frog

Homeostasis

- Water balance
- Heat balance
- Water and heat in the environment

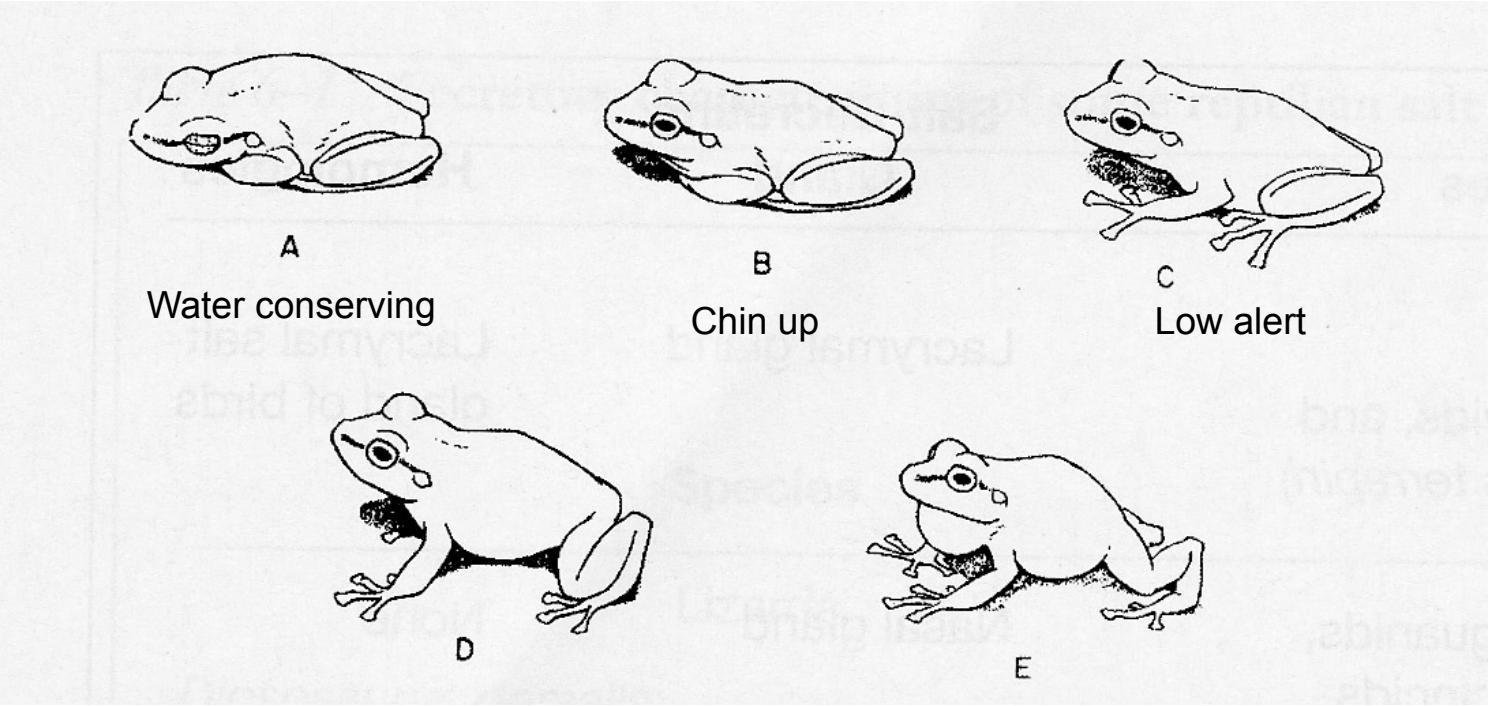
Managing water

- Herps have to manage water over both short and long time scales
- Use a variety of behavioral and physiological mechanisms

Short-term Water Balance

- Many herps have daily cycles related to water balance
- Especially common in terrestrial amphibians

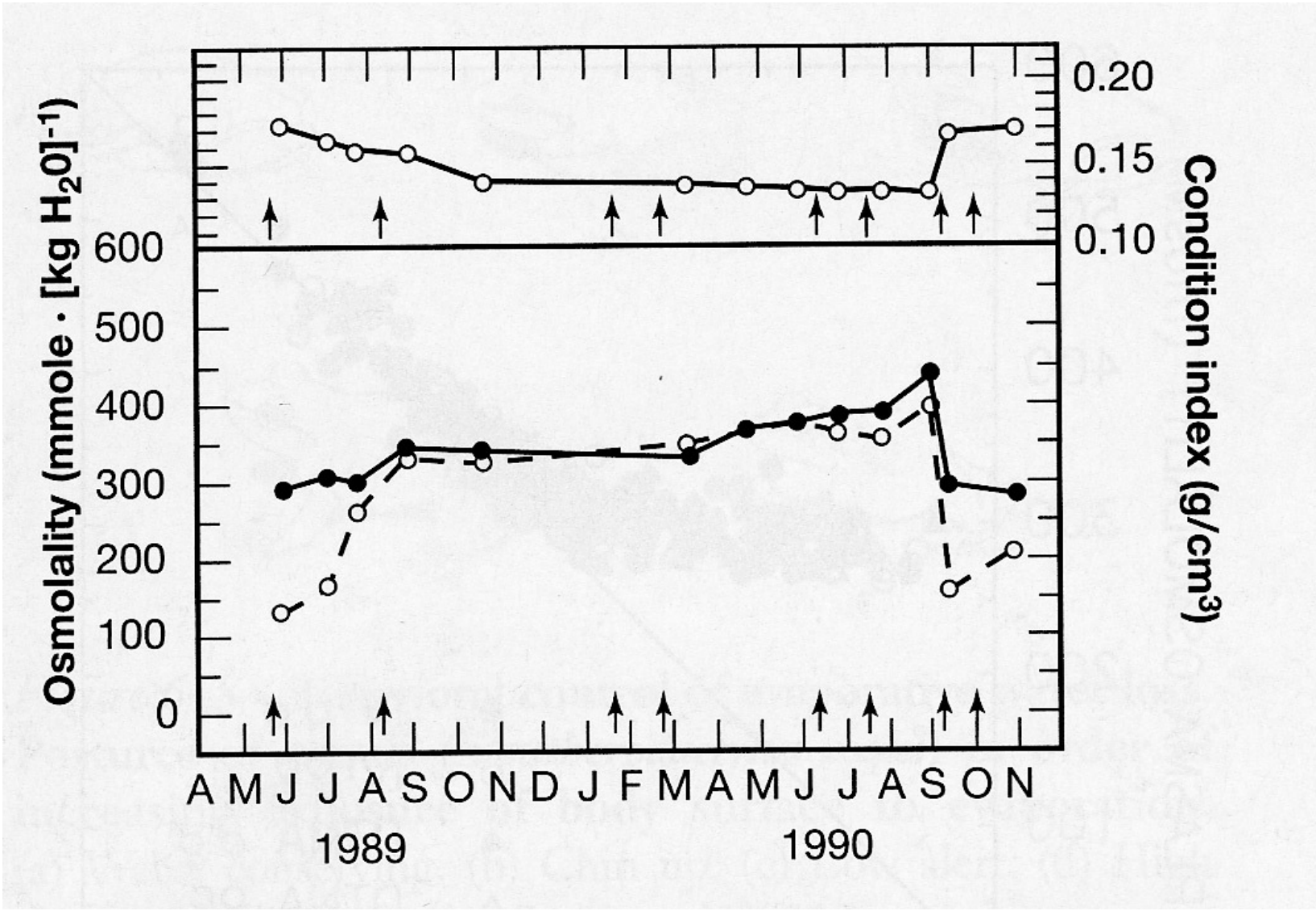
Example: Posture of coquí



Pough et al. 1983

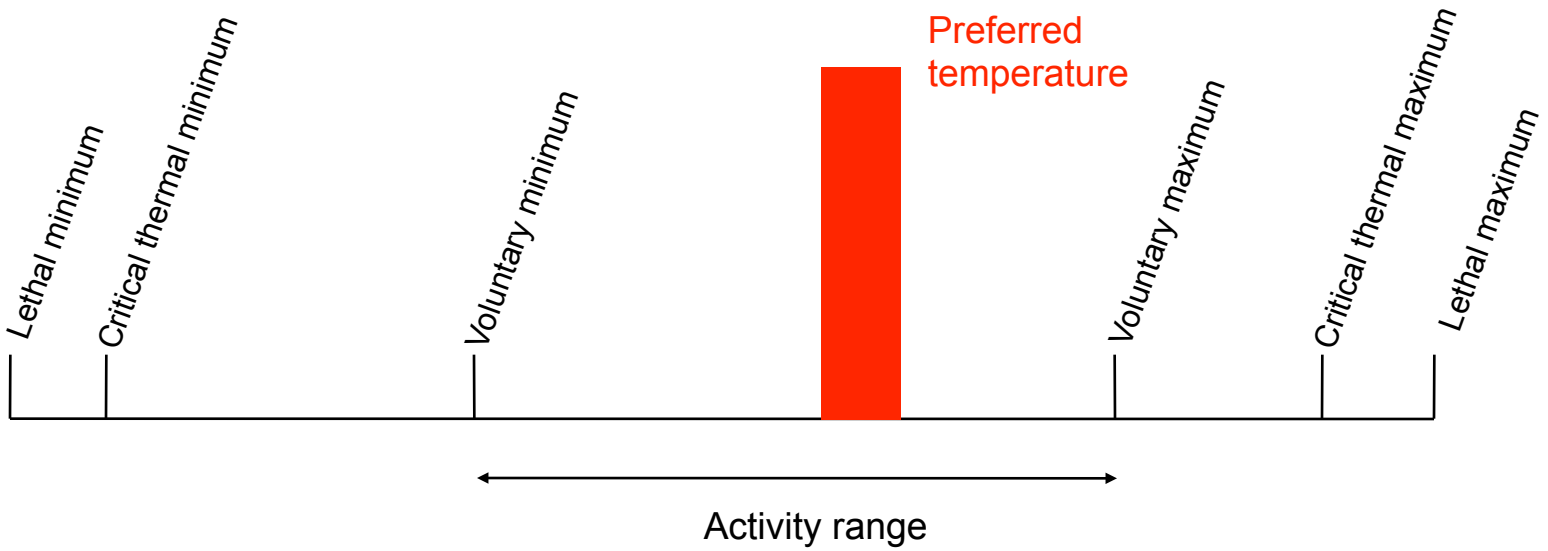
Long-term Water Balance

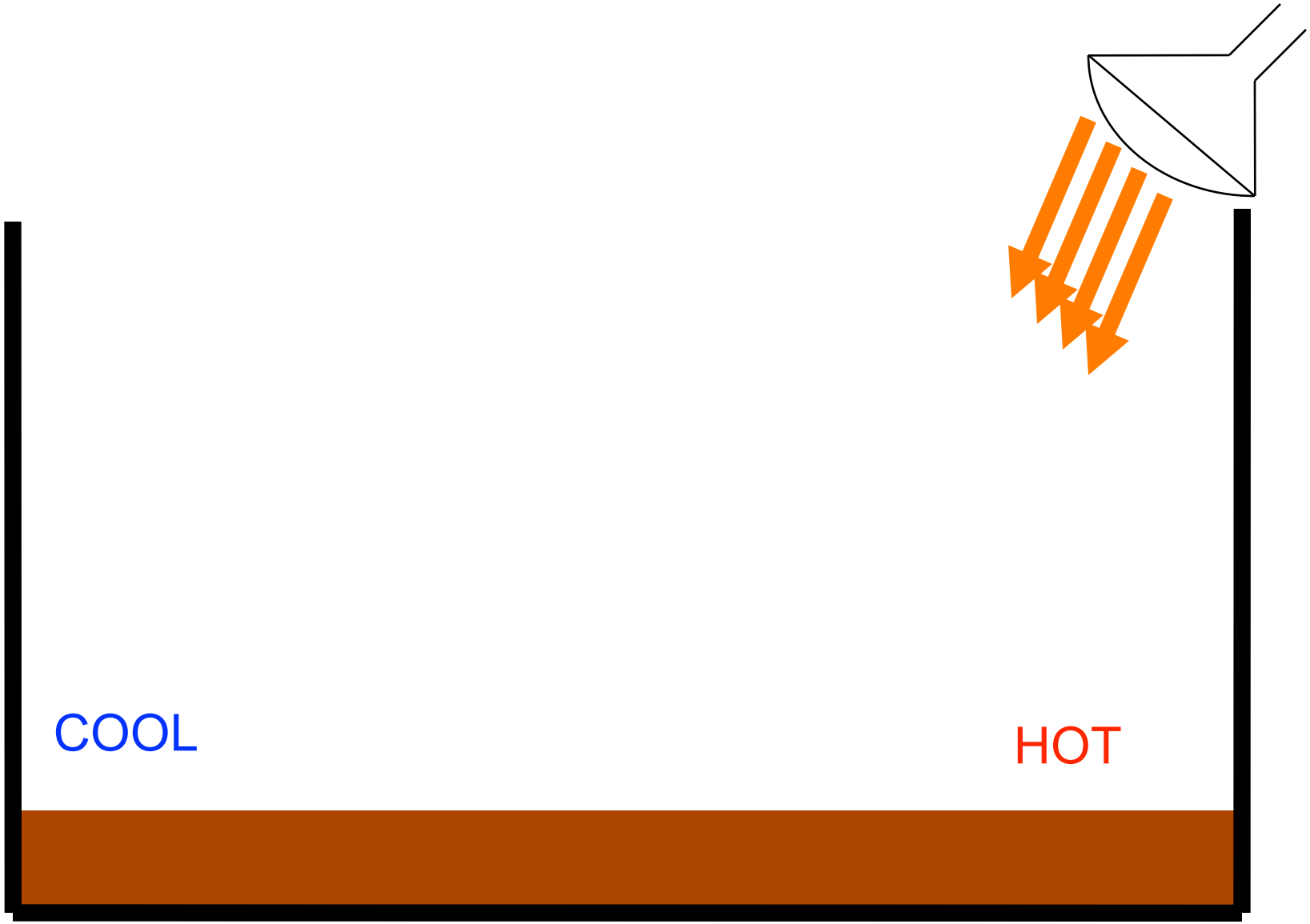
- Water flux is much slower in reptiles
- Water, salt can fluctuate over long time periods
- Example: desert tortoise

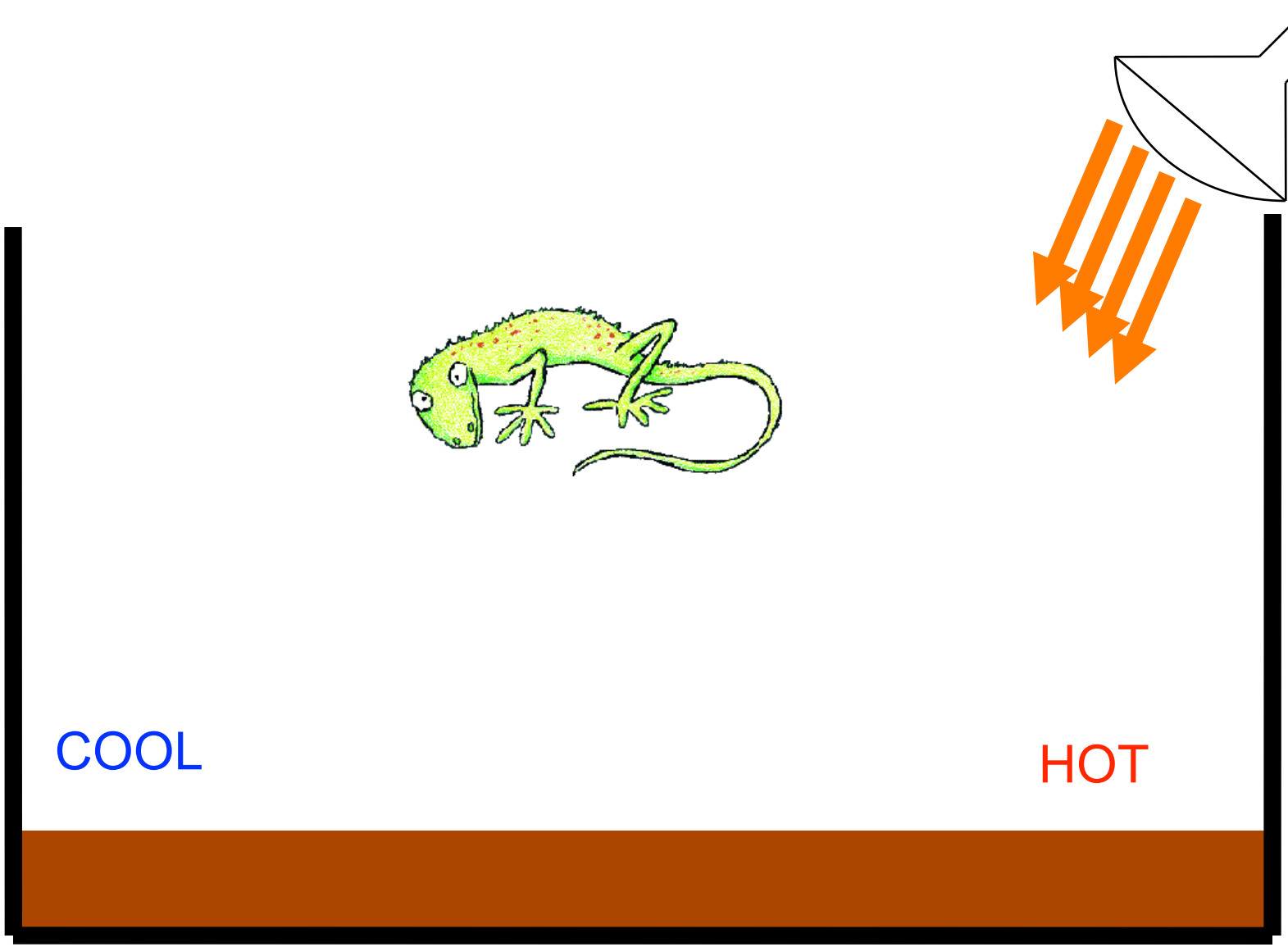

Osmolality (mmole · [kg H_2O]$^{-1}$)
600
500
400
300
200
100
0
0.20
0.15
0.10
Condition index (g/cm^3)
A M J J A S O N D J F M A M J J A S O N
1989
1990

Behavioral Thermoregulation

- Ectotherms are not “cold blooded”
- Most species maintain their body temperatures within a narrow range




COOL
HOT


COOL
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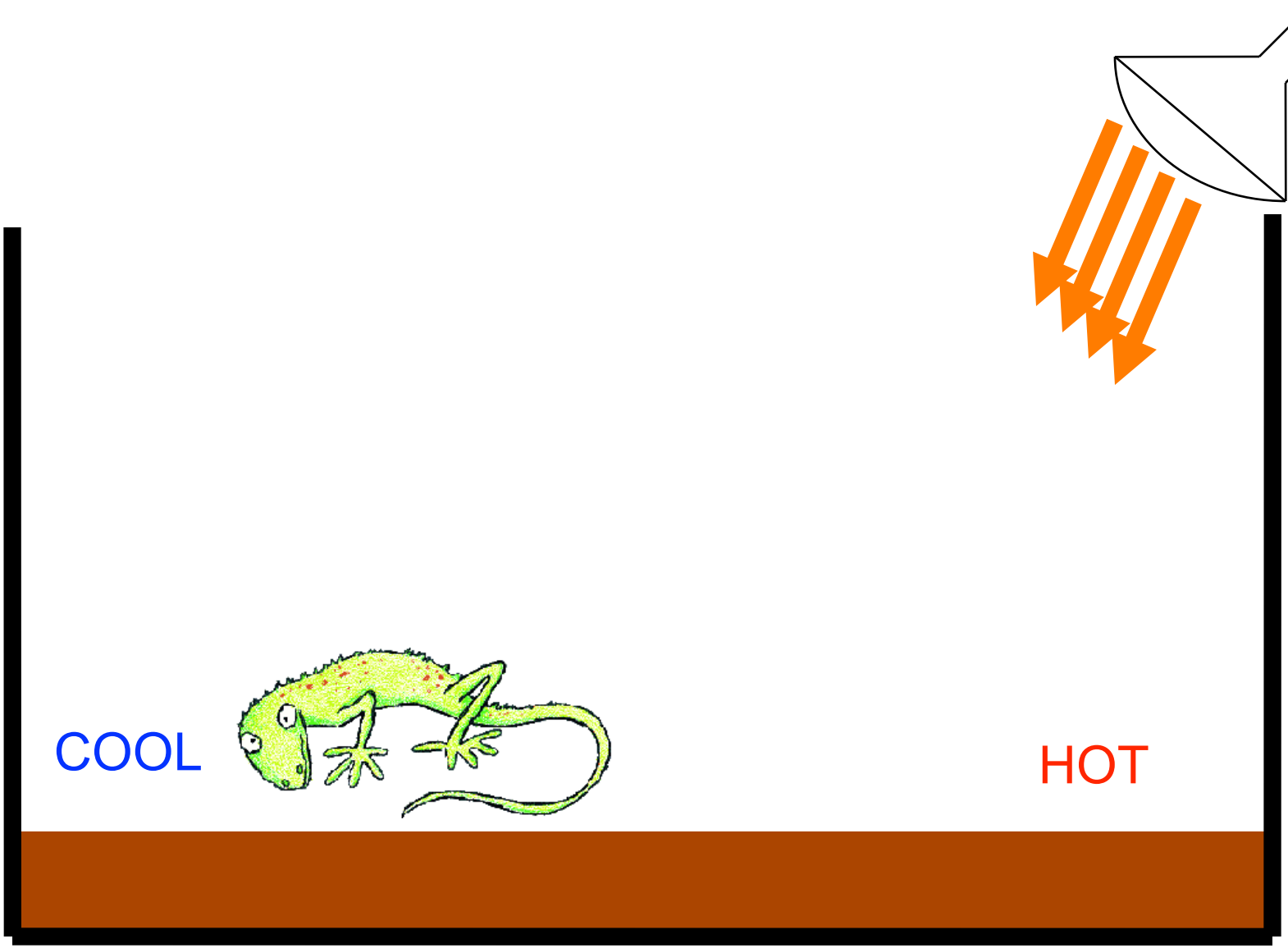
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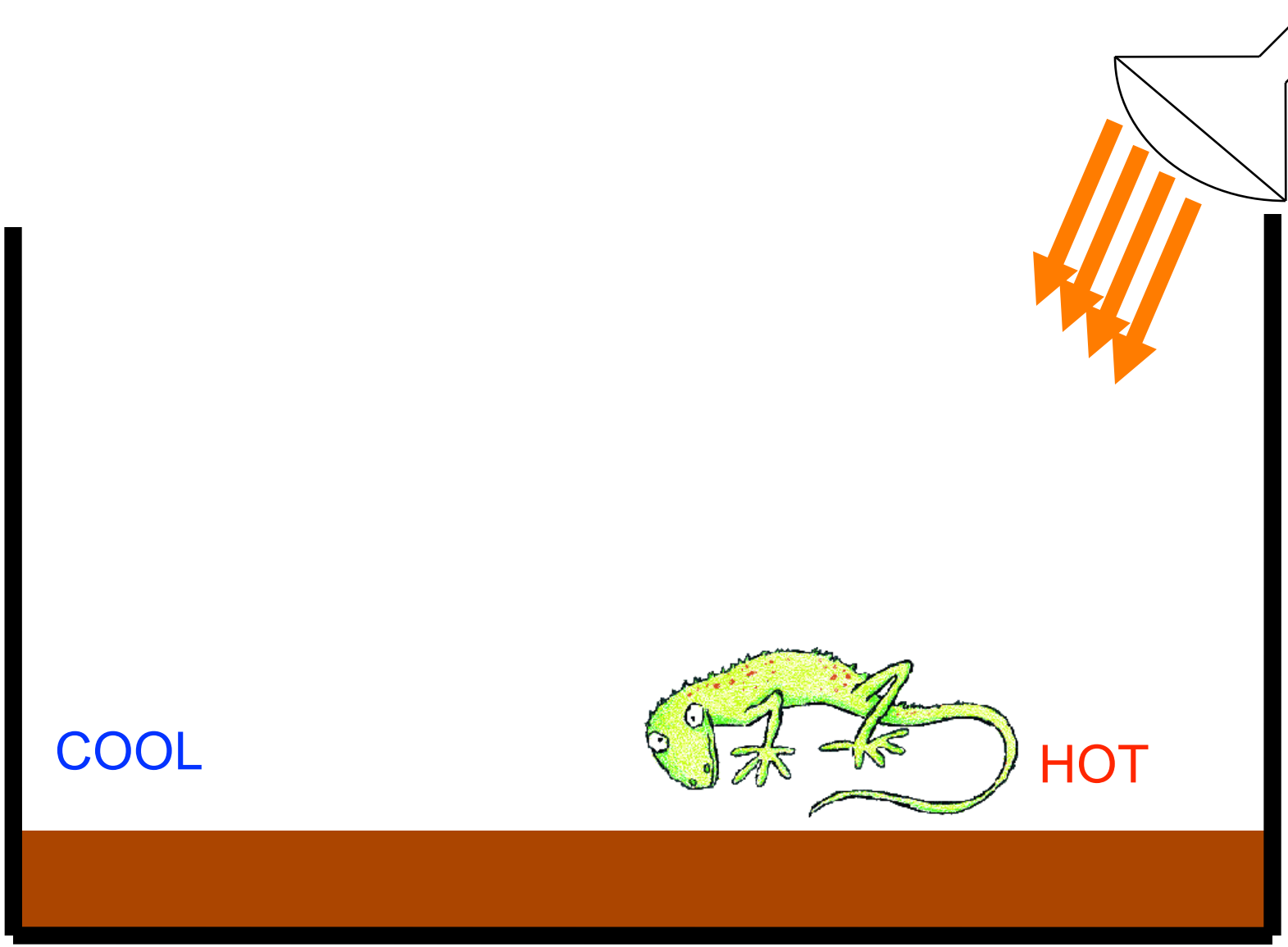
COOL
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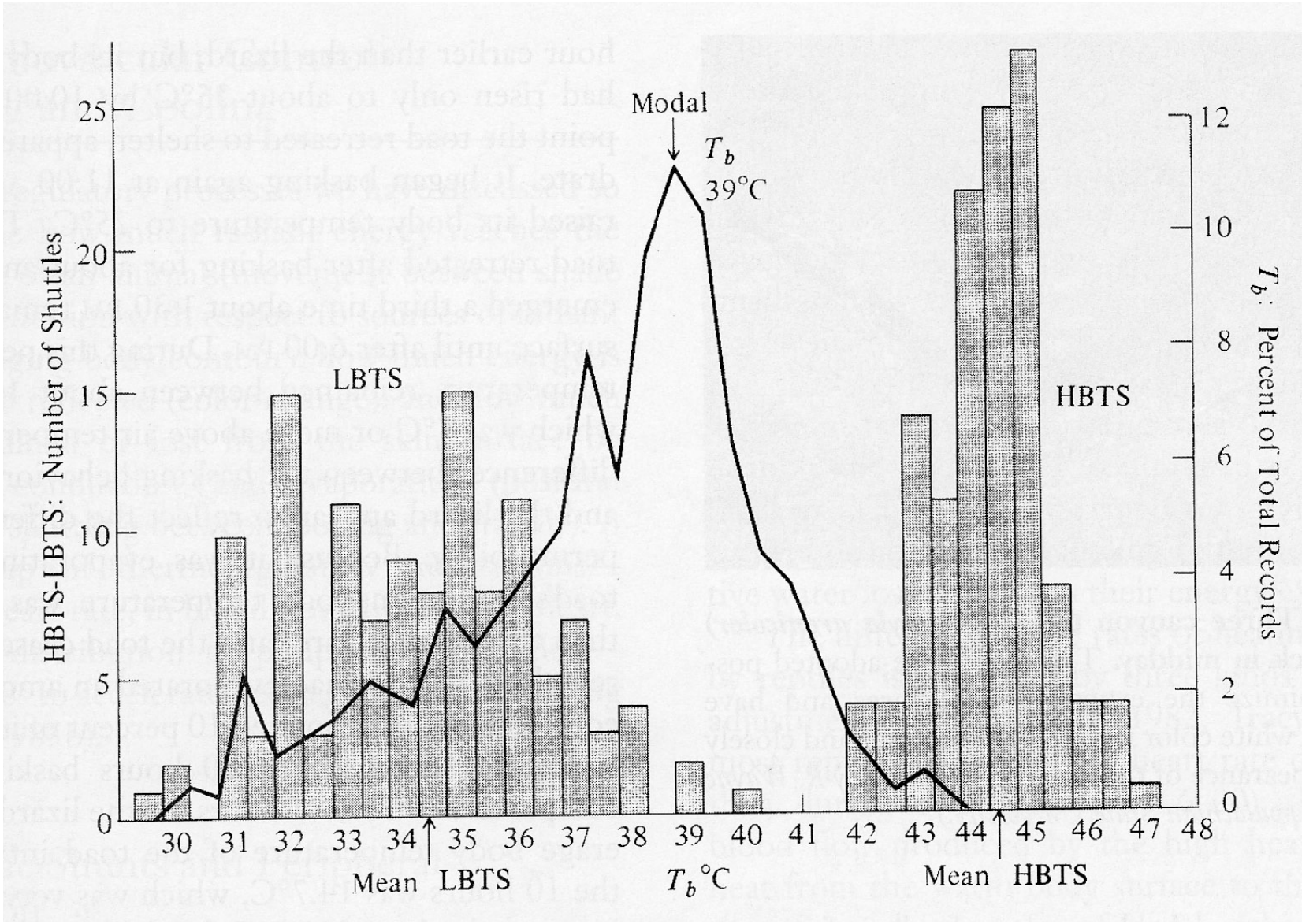

Desert iguana, *Dipsosaurus dorsalis*